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ABSTRACT

This document describes the parameterization of longwave radiation in the UCLA/GLAS general circulation model. Transmittances have been computed from the work of Arking and Chou for water vapor and carbon dioxide and ozone absorptances are computed using a formula due to Rodgers. Cloudiness has been introduced into the code in a manner in which fractional cover and random or maximal overlap can be accommodated. The entire code has been written in a form that is amenable to vectorization on CYBER and CRAY computers. Sample clear sky computations for five standard profiles using the 15- and 9-level versions of the model have been included.

1. INTRODUCTION

The parameterization of longwave radiation for general circulation models is currently under extensive study. Several experiments have shown that model integrations over long periods are very sensitive to the particular methods used in calculating the radiative terms. However, because of the spectral nature of radiation, an accurate description of the radiation field requires a summation over several spectral bands. Moreover, since the interaction paths are very long, transmittances between each atmospheric level and all other levels must be computed and carried through the spectral integration. Because of this, the computation of longwave radiation is the most time consuming step in the integration of a general circulation model. One common practice is to use a fairly detailed and accurate representation of the radiation, but to update the model infrequently, say every five hours, even if the physics is updated every half hour or hourly. The problem with this approach is that the life-cycle of clouds is often less than the time-interval of the update, and so there can be no interaction between radiation and cloudiness on shorter time scales. The need, therefore, is for a fast yet accurate treatment of longwave radiation.

2. RADIATIVE TRANSFER

For a clear atmosphere, the upward and downward fluxes at pressure level p , integrated over the spectral range $\Delta\nu$, can be written as

$$F_{\text{clr}}^{\uparrow}(p) = \int_{\Delta\nu} d\nu \left[B_{\nu}(T_s) \tau_{\nu}(p, p_s) + \int_{p_s}^p B_{\nu}(T(p')) \frac{d\tau_{\nu}(p, p')}{dp'} dp' \right] \quad (1a)$$

and

$$F_{\text{clr}}^{\downarrow}(p) = \int_{\Delta\nu} d\nu \left[\int_{p_t}^p B_{\nu}(T(p')) \frac{d\tau_{\nu}(p')}{dp'} dp' \right] \quad (1b)$$

where $B_{\nu}(T)$ is the blackbody flux at temperature T and wavenumber ν , $\tau_{\nu}(p, p')$ is the diffuse transmittance between the levels p and p' , and the subscripts s and t denote the surface and the top of the atmosphere, respectively. In order to use Equations (1a, b) as written, the spectral interval must be very narrow, since τ_{ν} varies very rapidly with wavenumber. In practice, models avoid this problem by resorting to certain assumptions regarding the distribution of spectral lines in the various absorption bands and constructing approximate band models.

We have adopted the method described by Chou and Arking (1980) and Chou (1984) for the water vapor bands, Chou and Peng (1983) for carbon dioxide and Rodgers (1968) for ozone. Table 1 lists the spectral regions covered for each of the bands in the model. Apart from line absorption in the various bands, there is also water vapor continuum absorption over a wide spectral region that overlaps with water vapor line absorption as well as the carbon dioxide and ozone absorption bands. This continuum absorptance, computed from a formula given by Roberts et al., (1976) is multiplied by the line transmittances where appropriate. Details are given in Chou and Kouvaris (1981).

An alternate form of the flux equations is obtained through integration by parts of (1a,b) reducing them to

$$F_{\text{clr}\uparrow}(p) = B(T(p)) + G(p, p_s, T_s) - G(p, p_s, T(p_s)) + \int_{T(p)}^{T(p_s)} \partial G(p, p', T(p')) / \partial T dT(p') , \quad (2a)$$

$$F_{\text{clr}\downarrow}(p) = B(T(p)) - G(p, p_t, T(p_t)) + \int_{T(p)}^{T(p_t)} \partial G(p, p', T(p')) / \partial T dT(p') , \quad (2b)$$

where

$$G(p, p', T) = \int_{\Delta\nu} \tau_\nu(p, p') B_\nu(T) d\nu , \quad (2c)$$

$$\partial G(p, p', T) / \partial T = \int_{\Delta\nu} \tau_\nu(p, p') \partial B_\nu(T) / \partial T d\nu . \quad (2d)$$

In the 9.6 μm and 15 μm bands, the spectral width of the band is sufficiently narrow such that a mean value of the Planck function may be used. That is,

$$G(p, p', T) = \int_{\Delta\nu} \tau_\nu(p, p') d\nu / \Delta\nu \cdot \int_{\Delta\nu} B_\nu(T) d\nu \quad (3)$$

For carbon dioxide, the spectral integration is performed separately over the band center from 620-720 cm^{-1} and the band wings from 540-620 cm^{-1} and 720-800 cm^{-1} . The transmittance in the ozone band is obtained by scaling the band absorptance given by Rodgers (1968), assuming that all absorption by ozone is confined to the 980-1100 cm^{-1} region. For water vapor, the variation of B_ν and τ_ν in (2c) is accounted for over the various spectral ranges. Details of the technique used to compute transmittances may be found in the references quoted above.

For cloudy skies, if an assumption is made that the clouds are black at thermal wavelengths, the above equations can be written very easily for a completely overcast sky by replacing the limits on the exchange integral, since transmission through a black cloud is zero. However, we have retained the possibility of allowing fractional cloud cover in the various model layers or

partial transmittance through high tenuous clouds. Therefore, a slightly different computational approach has been used utilizing the probability of a clear line of sight between each layer and all other layers, the ground and the top of the atmosphere. This will be explained in the description of the code.

The final result required by the dynamic model is the radiative cooling rate, or the divergence of the net flux. In terms of the quantities computed by Eqs. (2a, b) the cooling rate is

$$-\frac{dT}{dt} = \frac{g}{C_p} \frac{d}{dp} (F_{\downarrow} - F_{\uparrow}) \quad (4)$$

Of course, all other fluxes are available and the net flux at the surface is needed to perform the surface energy balance. For diagnostic purposes, the upward flux at the top of the atmosphere is also retained as output of the radiation model.

3. RADIATION CODE

In principle, if the atmospheric parameters such as temperature and mixing ratio of water vapor, carbon dioxide and ozone are given, the various transmittances required for the flux computation can be obtained using the theory covered in the various references cited earlier. In general, the transmittance depends on the atmospheric temperature, pressure and amount of absorbing gas. The atmosphere, however, is inhomogeneous in that the absorber amount, pressure and temperature are functions of altitude, and the absorbing path has to be suitably scaled in order to compute the transmittance. Again, the references cited explain the theory and techniques utilized. Practical difficulties arise when the exchange integrals in (2) are to be set in a numerical procedure to compute fluxes. The dynamic atmospheric model provides only the surface temperature and layer mean temperatures and mixing ratios for the model layers. However, the flux integrals are over a continuous atmospheric path, and the modeler is faced with the familiar problem of discretization. Since transmittance is a non-linear function of atmospheric path, widely varying results can be obtained depending on the assumptions made regarding the structure of temperature and mixing ratio between model levels. This problem of interpolation has been dealt with in various ways. Usually, the dynamic model layers are further subdivided and assumptions made about the profiles within the layer. Even after this, different quadrature schemes can yield different results, especially over paths where the transmittance varies rapidly.

In the radiation code that we have designed, we have side-stepped the interpolation problem by computing absorber amounts assuming that the mixing ratio of absorbing gas in each atmospheric layer is constant. The flux computations require that the temperature be known at the layer interface (each level of the model). For this, we interpolate the temperature linearly in the logarithm of

pressure for all levels except the top and bottom of the planetary boundary layer which is the lowest layer of the model. The temperature at the top and bottom of this layer is computed by following the appropriate adiabat. The dynamic model furnishes information up to the highest layer in the model, but there is some residual opacity in the upper atmosphere that, if ignored, could influence fluxes and cooling rates in the upper layers of the model. Usually, some radiation layers are inserted above the model layers and climatological information regarding temperature and mixing ratios supplied to the radiation code. In the 15-level UCLA model, the uppermost layer is centered at 1.4 mb with its bottom at 1.9 mb, and its upper boundary at 1 mb. We insert one radiation layer between 0 and 1 mb, and specify the temperature and mixing ratios in this layer, for example that they are the same as those in the top layer of the model.

The description of the radiation code is given below in separate sections for each subroutine and a listing is attached in the appendix. The code as presented is designed for clarity rather than optimization. It is also written so that it can be vectorized quite easily for use on CYBER and CRAY machines. Only key statements are explained with references to the papers from which the equations were obtained.

SUBROUTINE RADIR

This is the driving program of the longwave radiation code. The input to this code is the atmospheric profile of temperature and gaseous constituents. The input parameters passed to the subroutines are copied into internal variables. NDATA is the number of layers in the model which is 15 for the 15-level UCLA GCM. The other variables are as follows.

PU = pressure at each level of the model

PA = pressure at the middle of each layer

TA = mean temperature of the layer defined at pressure PA

TS = surface temperature

WA = water vapor mixing ratio of the layer defined at pressure PA

OA = ozone mixing ratio of the layer defined at pressure PA

CSS = random overlap cloud fraction

CCU = maximum overlap cloud fraction

The pressure at the top and bottom of the extra layer inserted on top of the dynamic model is designated PU(1) and PU(2) and defined. The cloud fraction in this layer is 0.0 and all other cloud fractions are constrained to lie between 0.0 and 1.0. After calls to the other subroutines, the fluxes at each level are returned to RADIR for the computation of cooling rates using (4). The term FAC is a conversion factor and since fluxes are in c.g.s. units, a conversion is also applied to obtain the upward flux at the top of the atmosphere (ULWTOP), the downward flux at the surface (DLWBOT) and the net upward flux at the surface (RS) in Wm^{-2} . The cooling rates in the 15 model layers are returned to the main program and are in $^{\circ}\text{C day}^{-1}$.

SUBROUTINE INDATA

When the program is run for the very first time, data is read in through this subroutine call. The data concerns the G-function and temperature corrections in the water vapor bands and is stored in tables. There is a subroutine call to a table look up program that computes the relevant numbers. This will be discussed later.

SUBROUTINE SETUP

This routine does some housekeeping on the input variables and also performs the temperature interpolation and computes scaled absorber amounts. At the end of the interpolation, the variables are on a vertical grid as shown in Figure 1. The amount of water vapor and ozone in each layer is computed from

$$U(p_1, p_2) = \frac{1}{g} \int_{p_1}^{p_2} q \, dp \approx \frac{q}{g} \Delta p_{1,2} \quad (5)$$

where q is the mixing ratio.

A factor of 1.02 is used to convert the pressure to c.g.s. units and divide in the acceleration constant. Some points to note are that there is a lower limit on the allowed mixing ratio. This is to prevent numerical problems at later stages.

Although (5) gives the amount of water vapor in a column of air from p_1 to p_2 as mentioned earlier, it is necessary to scale this amount to compute the transmission. In the routine we have defined three scaled water vapor absorption paths, one each for the band centers and band wings and one for e-type absorption. The path for band absorption is of the form

$$w_1(p_1, p_2) = \int_{p'}^p (p''/p_r)^m R(T(p''), T_r) q(p'') \, dp''/g \quad (6)$$

and for e-type absorption is

$$w_3(p_1, p_2) = \int_{p'}^p e(p'') \cdot \exp[1800 (1/T(p'') - 1/T_0)] q(p'') \, dp''/g. \quad (7)$$

The temperature dependent function R in (6) is written as SZ1 for the band center and SZ2 for the band wings and is given by

$$R(T, T_r) = \exp [r(T - T_r)] \quad , \quad (8)$$

where $r = 0.005$, $T_r = 225^\circ\text{K}$ for the band centers and $r = 0.016$ and $T_r = 256^\circ\text{K}$ for the wings. The reference pressure, p_r , is 275 mb for the center and 550 mb for the wings and $m = 1$ for both. In (7), $e(p'')$ is the water vapor partial pressure in atmospheres and $T_0 = 296^\circ\text{K}$. The equation is coded as $XX = \dots\dots\dots$ with UBAR denoting the scaled path length, w_3 , from each pressure level to the top of the atmosphere. The factor 630 in the code converts mixing ratio to vapor pressure in atmospheres and is (0.622×1013) and explained in Chou and Kouvaris (1981).

VBAR and WBAR are respectively, the scaled path lengths in the band center and wings. UBARM, VBARM and WBARM are the means of path lengths from two adjacent layers to the top, a quantity that is required later in the computation of transmission.

The scaled amount of carbon dioxide denoted by PSCALV for the band center and PSCALW for the wings is obtained from (6) with $c(p'')$ replacing $q(p'')$ where the concentration of CO_2 is in ppm. A conversion factor of 0.26 for 330 ppm is used here. Any other concentration can be used by changing the number accordingly since scaling in c is linear. The reference pressure, p_r , is 30 mb in the center and 300 mb in the wings while $m = 0.85$ in the center and 0.5 in the wings. For pressures $p < p_c$, the pressure scaling is (p_c/p_r) where $p_c = 1$ mb. The temperature scaling $R(T, T_r)$ is written as in (8) with $r = 0.0089$ in the center and 0.025 in the wings; $T_r = 240^\circ\text{K}$ for both regions. As in water vapor, the mean scaled path lengths PSCAMV and PSCAMW are also computed.

The ozone amount is given by (5) without any temperature scaling replacing q by the ozone mixing ratio. Additionally a quantity called the effective broadening pressure for a path is required and this is given by

$$\tilde{p} = \frac{\int_{p_1}^{p_2} q p dp}{\int_{p_1}^{p_2} q dp} \quad (9)$$

The ozone amount is coded as V while the numerator of (9) is coded as U in the subroutine. Additionally mean quantities UM and VM are also computed.

SUBROUTINE IRFLUX

This subroutine computes the fluxes in each of the bands in turn and adds them up. The various terms in (2a,b) are computed by calls to other subroutines that calculate the appropriate transmission functions.

The G-functions for water vapor defined by (2c,d) are computed here. As explained in Chou (1984),

$$G(w_1, w_3; T) = \tau(w_1, w_3; T) B(T) \quad (10)$$

where w_1, w_3 are defined by (6) and (7) and $B(T)$ is the Planck function at T integrated over the wavelength interval in question. The transmission, $\tau(w_1, w_3; T)$ is itself parameterized as

$$\tau(w_1, w_3; T) = \tau(w_1, w_3; 250)[1 + \alpha(w_1, w_3)(T - 250) + \beta(w_1, w_3)(T - 250)^2] \quad (11)$$

The quantities, $\tau(w_1, w_3; 250)$, α and β are obtained from a table lookup through a call to subroutine TABLE or a parameterization in subroutine GFUNC. For the band center, only w_1 is needed whereas for the band wings both w_1 and w_3 are needed. Note that w_1 is scaled differently for the center and wings, such that the passing argument to TABLE or GFUNC contains three path lengths UBAR, VBAR and WBAR.

The downward flux is computed from (2b) for which the terms $G(p, p_t, T(p_t))$ and $\int_{p_t}^{p_t} \Delta G(p, p, T(p))$ are required. In the code, $G(p, p_t, T(p_t))$ is called SHT and is computed for each level in the model starting with the second level and proceeding down to the surface. By definition, the downward flux at the topmost radiation level, 0 mb, is zero and so no computations are performed for that level. For each level, the term ΔG is computed with respect to all other layers following an approximation given in Chou and Kouvaris (1981). Basically, the approximation states that the contribution to the exchange integral at level I from a layer J is the product of the change in Planck function across the layer J and the transmission from the middle of layer J to level I hence the need for computations of mean absorber amounts in SETUP. The terms ΔG are called SG in the code for both upward and downward fluxes. Note that SG is two-dimensional and only one half of the array is used for the downward flux, whereas the other half is used for the upward flux. For the upward flux, $[G(p, p_s, T_s) - G(p, p_s, T(p_s))]$ is called SHU and is computed for each level except the surface.

The Planck function integrated over the spectral range in each band is computed by linear interpolation from tables given by DATA statements. The nomenclature is

SV = Planck function in water vapor band center

SW = Planck function in water vapor band wings

BAI = Planck function in 15 μm region

BWI = Planck function in 9.6 μm region

SH = Planck function integrated over entire spectrum

The terms in the flux equation in the 9.6 and 15 μm region are computed after calls to subroutine TRCO3 which returns the transmission in the 15 μm region as TAUF and in the 9.6 μm region as TXUF. These, when multiplied by the appropriate difference in Planck function across the layer are added to the SG calculated for water vapor.

After G and ΔG are computed, the upward and downward fluxes, FU and FD are calculated. For the clear sky, all cloud parameters CS, CC and CH are unity and the fluxes are simply summations of ΔG over the appropriate layers. The variable SG is summed in SUM and the downward flux is written as

$$FD = SUM - SHT + SH$$

while the upward flux is written as

$$FU = SUM + SHU + SH$$

following (2a,b). The upward flux at the surface is the black body flux since the surface is assumed to have unit emissivity in this code. Therefore, for the surface, $FU = SH$.

SUBROUTINE TRCO3

This subroutine computes the transmittance in the CO₂ and O₃ regions given

the scaled atmospheric paths for the various absorbers.

The transmittance in the 15 μ m region is expressed as

$$\tau(w_1, w_2, w_3) = \tau(w_1) \cdot \tau(w_2) \cdot \tau(w_3) \quad (12)$$

where subscripts 1, 2 and 3 refer to water vapor line, CO₂ line, and water vapor e-type absorption, respectively and the multiplicative property of transmittances has been used. Expressions for $\tau(w_1)$ and $\tau(w_3)$ in this region are given in Chou (1984) and are

$$\tau(w_1) = \exp [-6.7w_1/(1 + 16w_1^{0.6})] \quad (13)$$

and

$$\tau(w_3) = \exp (-27w_3^{0.83}) \quad (14)$$

The CO₂ band transmittance is expressed as

$$\tau(w) = \exp [-aw/(1 + bw^n)] \quad (15)$$

for both the band center and wings. The values of a, b and n are given in Chou and Peng (1983). Note that the wide band model has been used here. The transmittance $\tau(w_2)$ is given by suitably weighting (15) in the band center and wings, i.e.

$$\tau(w_2) = \frac{1}{\Delta v} [\tau_c \Delta v_c + \tau_w \Delta v_w] \quad (16)$$

where c and w refer to the center and wings respectively. For the model used here, $\Delta v_c = 100 \text{ cm}^{-1}$ and $\Delta v_w = 160 \text{ cm}^{-1}$ and the ratio of weights is therefore 5:8. The transmittance is denoted by TAUF and passed back to IRFLUX.

The transmittance in the 9.6 μ m region is computed by a modification of the band absorptance formulation given in Rodgers (1968). If we assume that all the ozone absorption is restricted to the 980-1100 cm^{-1} interval, then the average transmittance in that interval based on Rodgers' formula is

$$\tau_{O_3} = 1 - \frac{81.21}{120.0} [1 - \exp(-4.398 \bar{p} \{ \sqrt{1 + 4 \left(\frac{345.28 U_{O_3}}{0.876 \bar{p}} \right) - 1} \})] \quad (17)$$

where U_{O_3} is the column amount of ozone expressed in gcm^{-2} and \bar{p} is the effective broadening pressure in atmospheres. If \bar{p} is the mean pressure of the atmospheric layer and Δp is the pressure thickness of the layer in mb and X is the ozone mixing ratio in g/g in the layer, then

$$U_{O_3} = 1.02 X \Delta p \quad (18)$$

for each layer and the path through several contiguous layers is

$$U_{O_3} = \sum_i 1.02 X_i \Delta p_i \quad (19)$$

The effective broadening pressure in atmospheres, for a path through several contiguous layers is

$$\bar{p} = \left[\frac{\sum_i X_i p_i \Delta p_i}{\sum_i X_i \Delta p_i} \right] / 1013.25 \quad (20)$$

The ozone amounts and the numerator of (20) were calculated in SETUP and are passed from IRFLUX. A note of caution here is that if OZAI in SETUP is very small, there is a danger of computational overflow in using (20). This can be rectified by setting a small non-zero value for OZAI if OZAI is zero or very nearly so. If the model is to be run without ozone, XZ = 1.0 in the subroutine.

The transmittance in the ozone band has to be multiplied by the transmittance in the water vapor continuum that overlaps this region. The weak water vapor line absorption is neglected so only w_3 computed by (7) is needed. The transmittance is given in Chou (1984) and is

$$\tau(w_3) = \exp(-9.79 w_3) \quad (21)$$

and is denoted by TXUF.

SUBROUTINE TABLE

Calls to this subroutine are made to compute $\tau(w_1, w_3; 250)$, $\alpha(w_1, w_3)$ and $\beta(w_1, w_3)$ as defined by (11). Tables are read in at the start of the program and during an integration the values are interpolated and returned to the calling subroutine. A description of the table and the tables themselves are given in Chou (1984). The table is used only for the water vapor bands. For the band center, the quantities are a function only of w_1 for the center, called B in the subroutine. τ , α and β are given at regular intervals in $\log_{10} w_1$; there are 22 values from $\log_{10} w_1 = -6.0$ to $\log_{10} w_1 = 0.3$. Extrapolation is permitted for larger values of $\log_{10} w_1$ but a check is made to ensure that $\tau \geq 0.0$. τ , α , β are returned as WV, YV, ZV, respectively.

For the band wings, both w_1 and w_3 determine τ , α and β and so the table is two-dimensional with 22 values of $\log_{10} w_1$ from $\log_{10} w_1 = -5.4$ to $\log_{10} w_1 = 0.9$ and 19 values of w_3 from 0.0 to 0.054. The scale for w_3 is linear unlike that for w_1 . In the wings, w_1 is WBAR, called A in the subroutine, while w_3 is VBAR, call C in the subroutine. Again a check is made to ensure that $\tau \geq 0.0$. The two-dimensional table lookup is linear in $\log_{10} w_1$ and w_3 . τ , α , β are returned as WW, YW, ZW, respectively.

Since the table lookup procedure cannot be vectorized very easily, we have tried to replace the table by polynomial fits valid in the range of the table. This subroutine called GFUNC is also provided in the code and has the same input and output arguments as TABLE.

SUBROUTINE CLOUDS

In the longwave, clouds are considered to be non-reflecting and are assumed to completely fill a model layer in the vertical. In the horizontal, clouds are permitted to occupy a fraction of the grid box or to be partially transmitting. In either case the cloud fraction is expressed as a number between 0.0 and 1.0,

with 0.0 corresponding to clear skies and 1.0 to a completely filled opaque cloud. A completely filled layer of thin clouds of given emissivity is designated by the same parameter between 0.0 and 1.0 since for non-reflecting clouds, partial filling and partial transmission are interchangeable. The cloudy sky fluxes are computed from the same set of equations as the clear sky with certain multiplicative cloudiness factors depending on probabilities of clear line of sight between levels. These probabilities are computed in SUBROUTINE CLOUDS, the input to which specifies cloud fraction in each level and also whether the clouds are randomly overlapped or maximally overlapped. In the program the two kinds of cloudiness are specified independently, with CSS referring to random overlap fraction and CCU to the maximum overlap fraction.

The flux equations for partially cloudy skies are given below for the simple case illustrated in Figure 2. Consider a 5 layer model with a cloud in layer 3. If that is the only cloudy layer and fractional cover is N , then (2b) for the downward flux at a level below the cloud can be written as

$$F_{\text{cloud}}(p) = B(T(p)) - (1 - N) G(p, p_t, T(p_t)) + (1 - N) \int_{T(p)}^{T(p_t)} \partial G(p, p', T(p')) / \partial T dT(p') \\ + N \int_{T(p)}^{T(p_{cb})} \partial G(p, p', T(p')) / \partial T dT(p') \quad (22)$$

where p_{cb} is the level of the cloud base, in this case, level 4. But (22) can be written as

$$F_{\text{cloud}}(p) = B(T(p)) - (1 - N) G(p, p_t, T(p_t)) + (1 - N) \int_{T(p_{cb})}^{T(p_t)} \partial G(p, p', T(p')) / \partial T dT(p') \\ + \int_{T(p)}^{T(p_{cb})} \partial G(p', p', T(p')) / \partial T dT(p') \quad (23)$$

by splitting the limits of the first integral. Noting that $G(p, p_t, T(p_t))$ involves the transmittance between level p and the top of the atmosphere, p_t , it is evident that $(1 - N)$ is the probability of a clear line of sight between

p and p_t since p is below cloud base. Similarly for all levels between p_{c_b} and p_t , the probability between p and p' is also $(1 - N)$. For levels between p and p_{c_b} the probability is 1.0. Therefore (23) can be written as

$$F_{cld} \uparrow(p) = B(T(p)) - C(p, p_t) G(p, p_t, T(p_t)) + \int_{T(p)}^{T(p_t)} C(p, p') \partial G(p, p', T(p')) / \partial T dT(p') \quad (24)$$

where $C(p, p')$ is the probability of a clear line of sight from p to p' . Comparing (24) with (2b), we see that the form is the same except for the multiplication of the factors $C(p, p_t)$ and $C(p, p')$. These are coded as CH and CS respectively. It can be shown that the upward flux above the cloud layer is given by

$$F_{cld} \uparrow(p) = B(T(p)) + C(p, p_s) [G(p, p_s, T_s) - G(p, p_s, T(p_s))] + \int_{T(p)}^{T(p_s)} C(p, p') \partial G(p, p', T(p')) / \partial T dT(p') \quad (25)$$

The probability of a clear line of sight from level p to the surface is coded as CC. These cloud factors CH, CC and CS are passed back to IRFLUX for flux computations.

If there are clouds in more than one layer, (24) and (25) can still be used but the cloudiness factor will depend on the fraction in each layer and cloud overlap. The problem of fractional cloud overlap is still under study and there is no consensus on the preferred form of overlap in general circulation models. This question is only of academic importance in models that assume either clear skies or complete overcast. In the current radiation code we allow for two kinds of overlap, random and maximum. These are illustrated in Figs. 3 and 4.

Only some selected probabilities of clear lines of sight will be illustrated. In Figs. 3 and 4 for example, N_1 , N_2 and $N_5 = 0.0$, and $C(6,1)$ can be seen to be

$$C(6,1) = \text{MIN} [(1 - N_3), (1 - N_4)] \quad (26)$$

for maximum overlap, where MIN is the minimum function. For random overlap,

$$C(6,1) = (1 - N_3) * (1 - N_4) \quad (27)$$

In obtaining C for downward flux, the probabilities are computed starting from the top going down using equations like (26) and (27). In general, cloud factors are of the form $C_{i,j}$ where i is the level at which the flux is to be computed and j is the level to which the probability of a clear line of sight is needed. For the downward flux, j = 1 corresponds to the factor CH in the code while for the upward flux if j is the lowest level of the model (surface), then the factor is CC in the code. The downward cloud factors are computed by

$$C_{i,j} = \text{MIN} [(1 - N_j), (1 - N_{j+1}), (1 - N_{j+2}) \dots (1 - N_{i-1})], \quad (28)$$

for maximum overlap and

$$C_{i,j} = (1 - N_j) * (1 - N_{j+1}) * (1 - N_{j+2}) * \dots * (1 - N_{i-1}) \quad (29)$$

for random overlap. The upward cloud factors are computed by

$$C_{i,j} = \text{MIN} [(1 - N_{j-1}), (1 - N_{j-2}), (1 - N_{j-3}), \dots (1 - N_i)], \quad (30)$$

for maximum overlap and

$$C_{i,j} = (1 - N_{j-1}) * (1 - N_{j-2}) * (1 - N_{j-3}) * \dots * (1 - N_i) \quad (31)$$

for random overlap. The cloud factors for maximum and random overlap are computed separately and then multiplied to give the final probability of clear line of sight. It is possible to have a maximum overlap cloud fraction and random overlap cloud fraction assigned to the same layer but it is unlikely that a model will be able to make such specifications. We anticipate that the most common usage will be for layers of maximally overlapped cloud fractions in consecutive layers

overlapped with a broken cloud layer or cirrus layer separated by clear layers. For example in Fig. 3, if N_1 was the fraction of randomly overlapped clouds in layer 1 with N_3 and N_4 the maximum overlap cloud fractions in layers 3 and 4 respectively and $N_2 = 0$ signifying a clear layer 2, then (26) would read

$$C(6,1) = \text{MIN} [(1 - N_3), (1 - N_4)] * (1 - N_1) \quad (32)$$

However, if the downward flux at level 3 was needed, the appropriate factor would be $C(3,1)$ and this would be given by

$$C(3,1) = (1 - N_1) \quad (33)$$

The cloud fractions in layers 3 and 4 would not enter into the computations since level 3 is above the two layers. This simple example illustrates the usage of SUBROUTINE CLOUDS.

4. SAMPLE COMPUTATIONS

The radiation code has been used to compute fluxes and cooling rates using five standard profiles shown in Tables 2-6. The input profiles are currently being used in an intercomparison project in which GLAS is a participant. The input parameters have been interpolated to the levels corresponding to the 15- and 9-layer versions of the UCLA/GLAS GCM.

The nomenclature used in the tables is as follows.

PA = pressure at the middle of each layer in mb
PU = pressure at the bottom of each layer in mb
TA = temperature of the layer defined at pressure PA in Kelvin
QL = water vapor mixing ratio in layer in g/g
O3 = ozone mixing ratio in layer in g/g
UP15 = upward flux at each level in 15-layer model in Wm^{-2}
UP9 = as above in 9-layer model
DN15 = downward flux at each level in 15-layer model in Wm^{-2}
DN9 = as above in 9-layer model
NT15 = net upward flux at each level in 15-layer model in Wm^{-2}
NT9 = as above in 9-layer model
CR15 = cooling rate in each layer in 15-layer model in Celsius/day
CR9 = as above in 9-layer model

The same profiles have been used for the two models. The 9-layer model has the same vertical structure as the nine lowest layers of the 15-layer model. The top of the 15-layer model is at 1.0 mb whereas the top of the 9-layer model is at 51.8 mb. Fluxes and cooling rates have been presented such that the values in layers or levels at the same pressure are in the same row in the table. Of course, results are not presented for the six upper layers missing in the 9-layer model. The cooling rates computed for the 9-layer model do not differ substantially

from the 15-layer results except for the top one or two layers of the model where the cooling rate itself is quite small. These results also compare favorably with results obtained for 31 layers using the same profiles. The version of the code used to obtain the results in the five tables used SUBROUTINE TABLE for the water vapor transmittance and computed the temperature at the top and bottom of the boundary layer by following a dry adiabat. However, the code given in the appendix uses interpolated temperatures for these two levels.

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TABLE 1

Spectral regions in the longwave radiation scheme.

	H ₂ O band centers	H ₂ O band wings	CO ₂ band center	CO ₂ band wings	O ₃ band
Spectral range (cm ⁻¹)	0-340 1380-1900	340-540 800-980 1100-1380 1900-3000	620-720	540-620 720-800	980-1100

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TABLE 2

TROPICAL PROFILE

L	PA	PU	TA	QL	O3
1	1.4	1.9	267.8	0.325E-05	0.557E-05
2	2.7	3.7	258.2	0.325E-05	0.890E-05
3	5.2	7.2	247.6	0.325E-05	0.105E-04
4	10.0	13.9	237.8	0.325E-05	0.123E-04
5	19.3	26.8	228.6	0.325E-05	0.101E-04
6	37.3	51.8	216.3	0.325E-05	0.505E-05
7	72.0	100.0	201.4	0.325E-05	0.920E-06
8	125.7	152.6	202.0	0.331E-05	0.216E-06
9	187.2	223.4	218.3	0.742E-05	0.149E-06
10	268.2	314.9	233.9	0.786E-04	0.999E-07
11	372.1	431.4	249.3	0.443E-03	0.751E-07
12	502.2	575.5	265.0	0.143E-02	0.656E-07
13	662.1	751.6	279.6	0.398E-02	0.588E-07
14	855.7	963.0	291.2	0.109E-01	0.541E-07
15	987.9	1013.0	298.7	0.158E-01	0.490E-07

SURFACE TEMPERATURE = 300.0

L	FLUXES WATTS PER SQUARE METER						COOLING RATES DEGREES / DAY	
	UP15	UP9	DN15	DN9	NT15	NT9	CR15	CR9
1	297.1		1.1		296.0		5.79	
2	297.0		1.6		295.4		5.28	
3	296.7		2.4		294.2		3.71	
4	296.2		3.5		292.7		2.37	
5	295.9		5.1		290.8		1.16	
6	296.0		7.0		289.1		0.01	
7	297.6	296.7	8.5	5.2	289.0	291.5	-0.03	0.04
8	299.6	299.6	10.3	8.3	289.2	291.3	0.09	0.17
9	302.5	302.5	13.8	12.3	288.7	290.2	0.43	0.47
10	308.1	308.1	23.0	21.8	285.1	286.3	1.79	1.81
11	318.3	318.3	52.7	51.6	265.6	266.7	2.39	2.39
12	336.5	336.5	103.8	102.8	232.7	233.7	2.17	2.17
13	364.5	364.5	168.9	167.9	195.6	196.6	2.18	2.19
14	400.2	400.2	250.2	249.2	150.0	151.0	2.47	2.48
15	447.2	447.2	359.0	358.3	88.2	88.9	3.53	3.55
16	459.3	459.3	392.0	391.4	67.3	67.9		

TABLE 3

MIDLATITUDE SUMMER PROFILE

L	PA	PU	TA	QL	O3
1	1.4	1.9	274.7	0.400E-05	0.606E-05
2	2.7	3.7	264.8	0.400E-05	0.103E-04
3	5.2	7.2	252.5	0.400E-05	0.134E-04
4	10.0	13.9	241.5	0.400E-05	0.147E-04
5	19.3	26.8	232.2	0.400E-05	0.104E-04
6	37.3	51.8	222.1	0.400E-05	0.583E-05
7	72.0	100.0	216.9	0.400E-05	0.270E-05
8	125.7	152.6	216.1	0.400E-05	0.955E-06
9	187.2	223.4	217.7	0.819E-05	0.471E-06
10	268.2	314.9	233.1	0.113E-03	0.240E-06
11	372.1	431.4	248.0	0.402E-03	0.151E-06
12	502.2	575.5	262.4	0.103E-02	0.103E-06
13	662.1	751.6	275.6	0.292E-02	0.756E-07
14	855.7	963.0	287.8	0.731E-02	0.582E-07
15	987.9	1013.0	293.1	0.110E-01	0.515E-07

SURFACE TEMPERATURE = 294.0

L	FLUXES WATTS PER SQUARE METER						COOLING RATES DEGREES / DAY	
	UP15	UP9	DN15	DN9	NT15	NT9	CR15	CR9
1	288.2		1.2		287.0		6.81	
2	288.1		1.8		286.2		6.31	
3	287.7		2.8		284.9		6.41	
4	287.1		4.0		283.1		5.83	
5	286.5		5.7		280.8		1.66	
6	286.2		7.9		278.3		0.68	
7	286.7	286.3	10.4	8.2	276.3	278.1	0.22	0.32
8	289.2	289.2	14.2	12.9	275.0	276.3	0.14	0.20
9	291.9	291.9	17.8	16.5	274.1	275.0	0.36	0.38
10	296.5	296.5	25.4	24.6	271.1	271.9	1.86	1.87
11	307.5	307.5	56.6	55.9	250.9	251.6	1.98	1.98
12	324.8	324.8	101.2	100.6	233.6	224.2	1.87	1.87
13	348.5	348.5	156.8	156.2	191.7	192.3	1.95	1.96
14	380.3	380.3	229.3	228.8	151.0	151.6	2.01	2.01
15	414.8	414.8	314.0	313.6	100.8	101.2	3.25	3.26
16	423.5	423.5	342.0	341.5	81.5	81.9		

TABLE 4

MIDLATITUDE WINTER PROFILE

L	PA	PU	TA	QL	O3
1	1.4	1.9	258.1	0.400E-05	0.779E-05
2	2.7	3.7	243.0	0.400E-05	0.113E-04
3	5.2	7.2	227.8	0.400E-05	0.116E-04
4	10.0	13.9	220.6	0.400E-05	0.108E-04
5	19.3	26.8	218.4	0.400E-05	0.921E-05
6	37.3	51.8	215.3	0.400E-05	0.691E-05
7	72.0	100.0	215.7	0.400E-05	0.355E-05
8	125.8	152.9	217.5	0.446E-05	0.165E-05
9	187.7	224.1	218.7	0.902E-05	0.871E-06
10	269.2	316.1	221.6	0.223E-04	0.347E-06
11	373.6	433.3	234.7	0.986E-04	0.150E-06
12	504.6	578.3	247.5	0.410E-03	0.848E-07
13	665.4	755.3	259.8	0.110E-02	0.550E-07
14	860.1	968.0	267.6	0.200E-02	0.467E-07
15	992.9	1018.0	271.5	0.257E-02	0.462E-07

SURFACE TEMPERATURE = 272.2

L	FLUXES WATTS PER SQUARE METER						COOLING RATES DEGREES / DAY	
	UP15	UP9	DN15	DN9	NT15	NT9	CR15	CR9
1	236.4		1.0		235.4		5.10	
2	236.2		1.3		234.9		3.99	
3	235.9		1.9		234.0		2.20	
4	235.6		2.5		233.1		1.45	
5	235.5		3.5		232.0		1.19	
6	235.6		5.5		230.1		0.78	
7	236.3	236.3	8.5	8.0	227.8	228.3	0.49	0.53
8	238.2	238.2	13.2	13.0	225.0	225.3	0.39	0.39
9	240.3	240.3	17.7	17.4	222.6	222.8	0.45	0.45
10	243.1	243.1	24.4	24.1	218.8	219.0	0.67	0.67
11	248.1	248.1	36.7	36.5	211.5	211.7	1.33	1.33
12	258.3	258.3	65.3	65.1	193.0	193.2	1.68	1.68
13	273.9	273.9	109.7	109.5	164.2	164.4	1.47	1.47
14	291.9	291.9	158.5	158.3	133.4	133.6	1.07	1.07
15	306.9	306.9	200.5	200.3	106.4	106.6	1.53	1.53
16	311.5	311.5	214.2	214.0	97.3			

TABLE 5

SUBARCTIC SUMMER PROFILE

L	PA	PU	TA	QL	O3
1	1.4	1.9	277.5	0.400E-05	0.570E-05
2	2.7	3.7	269.4	0.400E-05	0.979E-05
3	5.2	7.2	255.7	0.400E-05	0.132E-04
4	10.0	13.9	243.3	0.400E-05	0.119E-04
5	19.3	26.8	234.6	0.400E-05	0.811E-05
6	37.3	51.8	225.1	0.400E-05	0.519E-05
7	72.0	100.0	225.1	0.400E-05	0.368E-05
8	125.6	152.5	225.0	0.401E-05	0.163E-05
9	186.9	223.0	225.1	0.111E-04	0.787E-06
10	267.6	314.1	225.0	0.422E-04	0.314E-06
11	371.1	430.2	240.7	0.292E-03	0.145E-06
12	500.8	573.9	256.0	0.102E-02	0.997E-07
13	660.2	749.3	268.7	0.251E-02	0.689E-07
14	853.1	960.0	279.6	0.489E-02	0.515E-07
15	984.9	1010.0	286.0	0.697E-02	0.418E-07

SURFACE TEMPERATURE = 287.0

L	FLUXES WATTS PER SQUARE METER						COOLING RATES DEGREES / DAY	
	UP15	UP9	DN15	DN9	NT15	NT9	CR15	CR9
1	270.3		1.3		269.0		7.18	
2	270.1		1.9		268.2		6.93	
3	269.7		3.0		266.7		4.85	
4	269.0		4.3		264.7		2.91	
5	268.3		5.9		262.4		1.83	
6	267.8		8.2		259.6		0.97	
7	268.0	268.0	11.3	10.0	256.8	258.0	0.55	0.65
8	270.2	270.2	16.6	15.9	253.6	254.3	0.39	0.41
9	272.3	272.3	21.1	20.6	251.2	251.7	0.51	0.53
10	275.0	275.0	28.1	27.7	246.9	247.4	1.01	1.02
11	280.6	280.6	44.7	44.3	236.0	236.4	1.93	1.93
12	296.3	296.3	86.8	86.4	209.5	209.8	1.90	1.90
13	318.8	318.8	141.6	141.3	177.2	177.5	1.70	1.70
14	346.0	346.0	204.2	203.9	141.8	142.1	1.45	1.45
15	376.8	376.8	271.1	270.8	105.7	106.0	2.26	2.27
16	384.9	384.9	292.7	292.4	92.3	92.5		

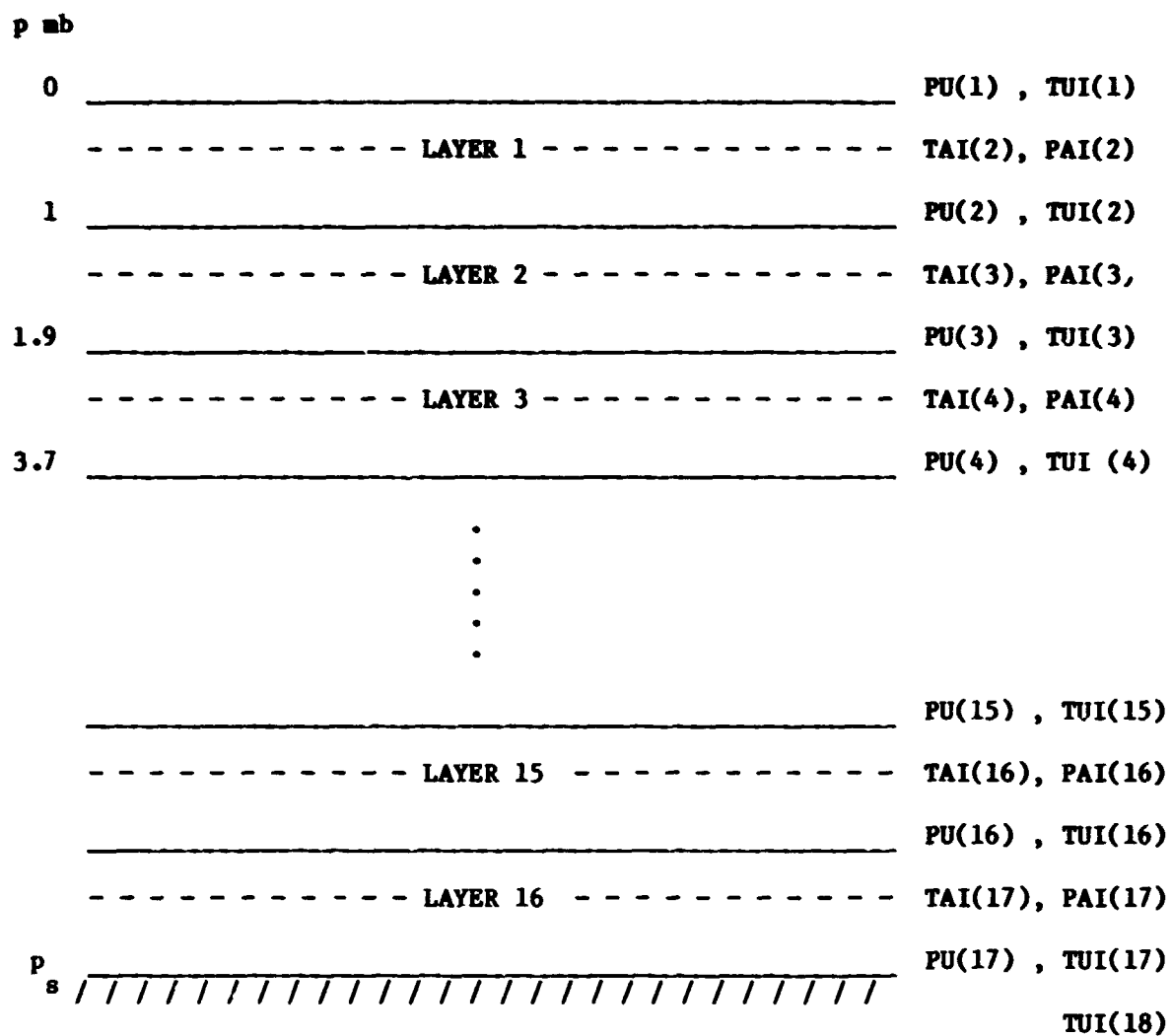
TABLE 6

SUBARCTIC WINTER PROFILE

L	PA	PU	TA	QL	O3
1	1.4	1.9	245.9	0.400E-05	0.932E-05
2	2.7	3.7	234.2	0.400E-05	0.124E-04
3	5.2	7.2	222.7	0.400E-05	0.121E-04
4	10.0	13.9	216.5	0.400E-05	0.920E-05
5	19.3	26.8	214.3	0.400E-05	0.871E-05
6	37.3	51.8	213.1	0.400E-05	0.780E-05
7	72.0	100.0	215.7	0.400E-05	0.528E-05
8	125.7	152.6	217.3	0.509E-05	0.249E-05
9	187.2	223.4	217.3	0.989E-05	0.129E-05
10	268.2	314.9	217.3	0.169E-04	0.428E-06
11	372.1	431.4	225.8	0.463E-04	0.131E-06
12	502.2	575.5	239.6	0.272E-03	0.649E-07
13	662.1	751.6	251.7	0.742E-03	0.474E-07
14	855.7	963.0	258.3	0.997E-03	0.355E-07
15	987.9	1013.0	257.5	0.898E-03	0.307E-07

SURFACE TEMPERATURE = 257.1

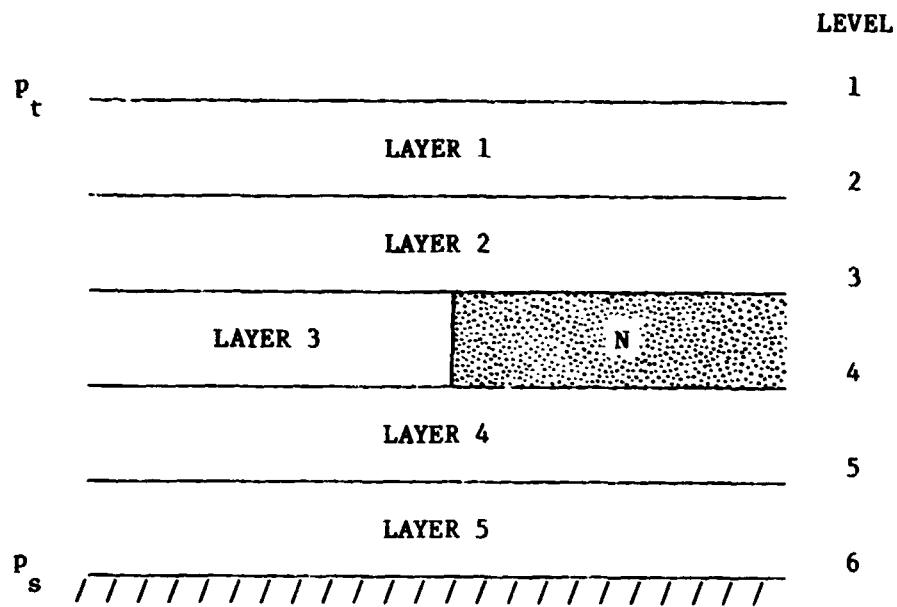
L	FLUXES WATTS PER SQUARE METER						COOLING RATES DEGREES / DAY	
	UP15	UP9	DN15	DN9	NT15	NT9	CR15	CR9
1	202.2		0.8		201.4		3.90	
2	202.1		1.1		201.0		3.22	
3	201.9		1.6		200.3		1.98	
4	201.6		2.1		199.5		1.35	
5	201.5		3.1		198.4		1.15	
6	201.6		4.9		196.7		0.86	
7	202.2	202.4	8.1	8.2	194.1	194.2	0.63	0.65
8	203.7	203.7	13.1	13.2	190.5	190.5	0.49	0.48
9	205.1	205.1	17.6	17.6	187.5	187.5	0.51	0.51
10	207.0	207.0	23.9	23.8	183.2	183.2	0.52	0.52
11	210.2	210.2	32.7	32.7	177.5	177.6	0.82	0.82
12	217.3	217.3	51.1	51.0	166.2	166.2	1.57	1.57
13	230.5	230.5	91.2	91.1	139.3	139.4	1.36	1.36
14	243.9	243.9	133.1	133.0	110.9	111.0	0.78	0.78
15	246.5	246.5	155.1	155.1	91.4	91.4	1.04	1.04
16	248.0	248.0	162.8	162.7	85.2	85.2		



Levels in the Radiation Model

FIG. 1

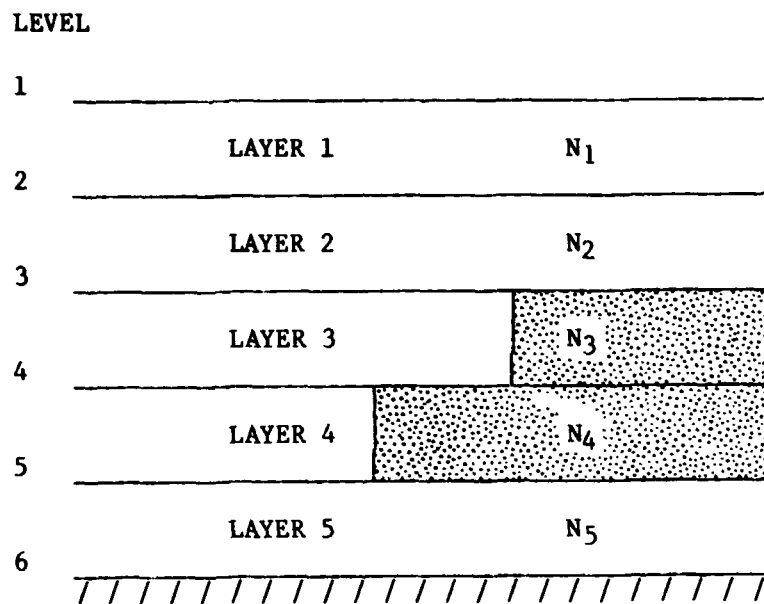
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Schematic showing partial cloudiness in one layer

FIG. 2

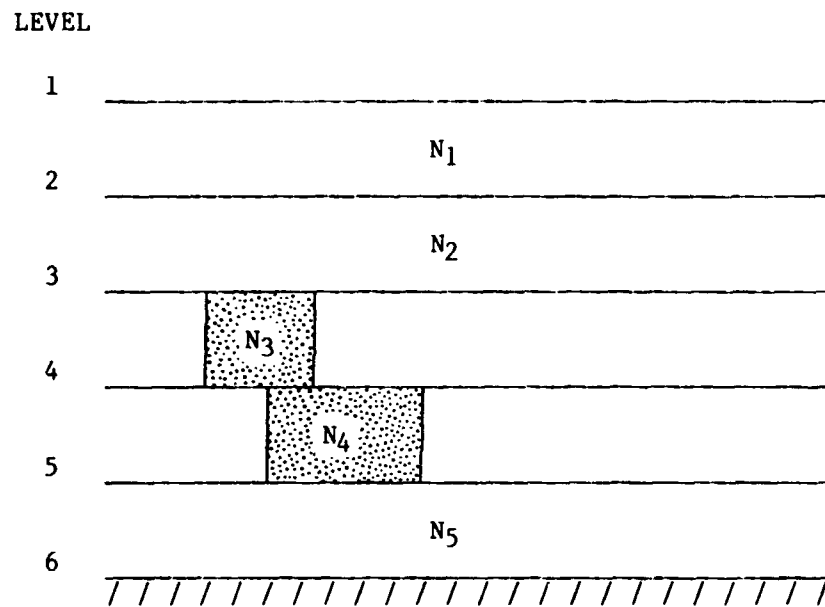
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Schematic showing maximum overlap

FIG. 3

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Schematic showing random overlap

FIG. 4

APPENDIX

CODE LISTING

NOTE: Several loops diagnosed by the compiler as being non-vectorizable can in fact be vectorized by using vector functions or slight restructuring. Since these are usually system-specific, the user is expected to make the necessary changes. A fully vectorized half-precision version of the code designed for the CYBER-205 that is currently being used in the GCM is available from the authors upon request.


```

0001      SUBROUTINE RADIR (LM,PL,PL20,TL,TG,QL,O3L,CLD,CLU,
      1      ATLX,RS,ULWTOP,DLWBOT)
      C
      C*****      INPUT PARAMETERS      *****
      C
      C      LM.....NUMBER OF LAYERS
      C      PL.....LAYER MIDDLE PRESSURE IN MB
      C      PL20....LAYER BOTTOM PRESSURE IN MB
      C      TL.....LAYER MIDDLE TEMPERATURE IN KELVIN
      C      TG.....SURFACE TEMPERATURE IN KELVIN
      C      QL.....WATER VAPOR MIXING RATIO IN G/G
      C      O3L.....OZONE MIXING RATIO IN G/G
      C      CLD.....RANDOM OVERLAP CLOUD FRACTION
      C      CLU.....MAXIMUM OVERLAP CLOUD FRACTION
      C
      C*****      OUTPUT PARAMETERS      *****
      C
      C      ATLX....LAYER COOLING RATE IN CELSIUS/DAY
      C      RS.....NET UPWARD FLUX AT SURFACE IN W/M**2
      C      ULWTOP...UPWARD FLUX AT TOP OF ATMOSPHERE IN W/M**2
      C      DLWBOT...DOWNWARD FLUX AT SURFACE IN W/M**2
      C
0002      DIMENSION PL (72,20) ,PL20 (72,20) ,TL (72,20) ,TG (72)
0003      DIMENSION QL (72,20) ,O3L (72,20) ,CLD (72,20) ,CLU (72,20)
0004      DIMENSION ATLX (72,20) ,RS (72) ,ULWTOP (72) ,DLWBOT (72)
0005      DIMENSION FE (72,20) ,COOLR (72,20)
0006      COMMON/FLUX/FD (72,20) ,FU (72,20)
0007      COMMON/AMHN/TA (72,20) ,PA (72,20) ,WA (72,20) ,OA (72,20)
      1,NDATA,TS (72)
0008      COMMON/CSC/CSS (72,20) ,CCU (72,20) ,CH (72,20) ,CC (72,20)
      1,CS (72,20,20)
0009      COMMON/PRESS/PU (72,20) ,DP (72,20)
0010      COMMON/INIT/NP,NPP1,NPM1
      C
0011      LOGICAL FIRST/.TRUE./
0012      IF (.NOT.FIRST) GO TO 10
0013      FIRST=.FALSE.
0014      CALL INDATA
      C
0015      10  CONTINUE
0016          NDATA=LM
0017          FAC=3.6*24./10030.*.98
0018          DO 20 I=1,72
0019              PU (I,1)=0.
0020              PU (I,2)=1.
0021              CSS (I,1)=0.
0022              CCU (I,1)=0.
0023              TS (I)=TG (I)
0024      20  CONTINUE
0025          DO 30 J=1,NDATA
0026              DO 30 I=1,72
0027                  PA (I,J)=PL (I,J)
0028                  PU (I,J+2)=PL20 (I,J)
0029                  TA (I,J)=TL (I,J)
0030                  WA (I,J)=QL (I,J)
0031                  OA (I,J)=O3L (I,J)
0032                  CSS (I,J+1)=CLD (I,J)
0033                  CCU (I,J+1)=CLU (I,J)
0034                  CSS (I,J+1)=AMAX1 (AMIN1 (CSS (I,J+1) ,1.0) ,0.)

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0035      CCU(I,J+1)=AMAX1(AMIN1(CCU(I,J+1),1.0),0.)
0036      30 CONTINUE
      C
0037      CALL SETUP
      C
0038      DO 40 IP=1,NP
0039      DO 40 IL=1,72
0040      FE(IL,IP)=FD(IL,IP)-FU(IL,IP)
0041      40 CONTINUE
0042      DO 50 I=1,72
0043      ULWTOP(I)=FU(I,1)*0.001
0044      DLWBOT(I)=FD(I,NP)*0.001
0045      RS(I)=-FE(I,NP)*0.001
0046      50 CONTINUE
0047      DO 60 IP=2,NP
0048      DO 60 IL=1,72
0049      COOLR(IL,IP)=(FE(IL,IP)-FE(IL,IP-1))*FAC/DP(IL,IP)
0050      60 CONTINUE
0051      DO 70 J=1,NDATA
0052      DO 70 I=1,72
0053      AT LX(I,J)=COOLR(I,J+2)
0054      70 CONTINUE
0055      RETURN
0056      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0026	LINE 0035 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0025	LINE 0026 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0018	LINE 0019 LHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES

NUMBER OF LOOPS IN ROUTINE = 0010

NUMBER OF VECTORIZABLE LOOPS = 0007

NUMBER OF STACKLIBED LOOPS = 0000

```

0001      SUBROUTINE INDATA
      C
      C*****      READ IN DATA      *****
      C
0002      COMMON/H2O/GL(30,20),COEFF(30,20,2)
0003      COMMON/INDAT/NUPI,NW
0004      NUPI=20
0005      NW=22
0006      READ(5,10) DUMMY
0007      10 FORMAT(A1,/,A1,/)
0008      READ(5,10) DUMMY
0009      READ(5,20)((GL(IW,IU),IW=1,NW),IU=1,NUPI)
0010      READ(5,10) DUMMY
0011      READ(5,20)((COEFF(IW,IU,I),IW=1,NW),IU=1,NUPI),I=1,2)
0012      20 FORMAT(11F7.4)
0013      RETURN
0014      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0011	LINE 0011 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0011	LINE 0011 STATEMENT IS NOT AN ASSIGNMENT STATEMENT
LINE 0009	LINE 0009 STATEMENT IS NOT AN ASSIGNMENT STATEMENT

NUMBER OF LOOPS IN ROUTINE = 0003

NUMBER OF VECTORIZABLE LOOPS = 0000

NUMBER OF STACKLIBED LOOPS = 0000

```

0001      SUBROUTINE SETUP
      C
      C
0002      DIMENSION PRE (2) ,PR (2)
0003      DIMENSION X2 (72,20) ,X4 (72,20) ,SZ1 (72,20) ,SZ2 (72,20) ,XX (72,20)
0004      DIMENSION RV (72,20) ,RW (72,20) ,PM (72,20) ,PMV (72,20) ,PMW (72,20)
0005      DIMENSION DPI (72,20) ,PAI (72,20) ,TAI (72,20) ,RAWI (72,20)
      *      ,OZAI (72,20)
0006      COMMON/PRESS/PU (72,20) ,DP (72,20)
0007      COMMON/TEMP/TUI (72,20)
0008      COMMON/INIT/NP,NPP1,NPM1
0009      COMMON/SH20/UBAR (72,20) ,VBAR (72,20) ,WBAR (72,20) ,UBARM (72,20) ,
      1      VBARM (72,20) ,WBARM (72,20)
0010      COMMON/SC0203/PSCALV (72,20) ,PSCALW (72,20) ,U (72,20) ,V (72,20) ,
      1      PSCAMV (72,20) ,PSCAMW (72,20) ,UM (72,20) ,VM (72,20)
0011      COMMON/AMHN/TA (72,20) ,PA (72,20) ,WA (72,20) ,OA (72,20) ,NDATA
      1,      TS (72)
0012      DATA PRE/275.,550./,PR/30.,300./,PP/1./
0013      NP=NDATA+2
0014      NPP1=NP+1
0015      NPM1=NP-1
0016      DO 10 IP=2,NP
0017      DO 10 IL=1,72
0018      DP (IL,IP)=PU (IL,IP) -PU (IL,IP-1)
0019      DPI (IL,IP)=DP (IL,IP) *1.02
0020      10 CONTINUE
      C
      C***** TEMPERATURE AND HUMIDITY INTERPOLATIONS *****
      C
0021      DO 20 J=1,NDATA
0022      DO 20 I=1,72
0023      WA (I,J)=AMAX1 (WA (I,J) ,0.1E-12)
0024      OA (I,J)=AMAX1 (OA (I,J) ,0.1E-12)
0025      20 CONTINUE
0026      DO 30 J=3,NP
0027      DO 30 I=1,72
0028      PAI (I,J)=PA (I,J-2)
0029      TAI (I,J)=TA (I,J-2)
0030      RAWI (I,J)=WA (I,J-2) *DPI (I,J)
0031      OZAI (I,J)=OA (I,J-2) *DPI (I,J)
0032      30 CONTINUE
0033      DO 40 J=3,NPM1
0034      DO 40 I=1,72
0035      X2 (I,J)=ALOG (PU (I,J) /PA (I,J-2))

```



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0036      X4(I,J)=ALOG(PA(I,J-1)/PA(I,J-2))
0037      TUI(I,J)=TA(I,J-2)+X2(I,J)/X4(I,J)*(TA(I,J-1)-TA(I,J-2))
0038  40    CONTINUE
0039      DO 50 I=1,72
0040      X2(I,NP)=ALOG(PU(I,NP)/PU(I,NPM1))
0041      X4(I,NP)=ALOG(PA(I,NDATA)/PU(I,NPM1))
0042      TUI(I,NP)=TUI(I,NPM1)+X2(I,NP)/X4(I,NP)*(TA(I,NDATA)
1        -TUI(I,NPM1))
0043      TUI(I,NPP1)=TS(I)
0044      DPI(I,1)=0.
0045      PAI(I,1)=0.
0046      PAI(I,2)=0.5*PU(I,2)
0047  50    CONTINUE
0048      DO 60 J=1,2
0049      DO 60 I=1,72
0050      TAI(I,J)=TA(I,1)
0051      TUI(I,J)=TA(I,1)
0052      RAWI(I,J)=WA(I,1)*DPI(I,J)
0053      OZAI(I,J)=OA(I,1)*DPI(I,J)
0054  60    CONTINUE
C
C***** COMPUTE SCALED WATER VAPOR AMOUNTS*****
C
0055      DO 80 IL=1,72
0056      UBAR(IL,1)=0.
0057      VBAR(IL,1)=0.0
0058      WBAR(IL,1)=0.0
0059  80    CONTINUE
0060      DO 90 IP=2,NP
0061      DO 90 IL=1,72
0062      SZ1(IL,IP)=EXP(0.005*(TAI(IL,IP)-225.0))
0063      SZ2(IL,IP)=EXP(0.016*(TAI(IL,IP)-256.0))
0064      VBAR(IL,IP)=VBAR(IL,IP-1)+RAWI(IL,IP)*SZ1(IL,IP)*
1        (PAI(IL,IP)/PRE(1))
0065      WBAR(IL,IP)=WBAR(IL,IP-1)+RAWI(IL,IP)*SZ2(IL,IP)*
1        (PAI(IL,IP)/PRE(2))
0066      XX(IL,IP)=(PAI(IL,IP)/630.)*RAWI(IL,IP)*RAWI(IL,IP)/DPI(IL,IP)
0067      XX(IL,IP)=XX(IL,IP)*EXP(1800./TAI(IL,IP)-6.0811)
0068      UBAR(IL,IP)=UBAR(IL,IP-1)+XX(IL,IP)
0069      UBARM(IL,IP)=0.5*(UBAR(IL,IP)+UBAR(IL,IP-1))
0070      VBAR(IL,IP)=0.5*(VBAR(IL,IP)+VBAR(IL,IP-1))
0071      WBARM(IL,IP)=0.5*(WBAR(IL,IP)+WBAR(IL,IP-1))
0072  90    CONTINUE
C
C***** COMPUTE SCALED CO2 AMOUNTS *****
C
0073      DO 100 IL=1,72
0074      PSCALV(IL,1)=0.
0075      PSCALW(IL,1)=0.
0076  100   CONTINUE
0077      DO 110 IP=2,NP
0078      DO 110 IL=1,72
0079      RV(IL,IP)=EXP(0.0089*(TAI(IL,IP)-240.0))
0080      RW(IL,IP)=EXP(0.025*(TAI(IL,IP)-240.0))
0081      PM(IL,IP)=AMAX1(PAI(IL,IP),PP)
0082      PMV(IL,IP)=(PM(IL,IP)/PR(1))*0.85*RV(IL,IP)
0083      PMW(IL,IP)=(PM(IL,IP)/PR(2))*0.5*RW(IL,IP)
C
C***** 0.26 IS FOR CO2=330 PPMV *****
C

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0084      PSCALV(IL,IP)=DP(IL,IP)*PMV(IL,IP)*0.26+PSCALV(IL,IP-1)
0085      PSCALW(IL,IP)=DP(IL,IP)*PMW(IL,IP)*0.26+PSCALW(IL,IP-1)
0086      PSCAMV(IL,IP)=0.5*(PSCALV(IL,IP)+PSCALV(IL,IP-1))
0087      PSCAMW(IL,IP)=0.5*(PSCALW(IL,IP)+PSCALW(IL,IP-1))
0088      110  CONTINUE
      C
      C***** COMPUTE SCALED OZONE AMOUNTS *****
      C
0089      DO 120 IL=1,72
0090      U(IL,1)=0.
0091      V(IL,1)=0.
0092      120  CONTINUE
0093      DO 130 IP=2,NP
0094      DO 130 IL=1,72
0095      U(IL,IP)=PAI(IL,IP)*OZAI(IL,IP)+U(IL,IP-1)
0096      V(IL,IP)=OZAI(IL,IP)+V(IL,IP-1)
0097      UM(IL,IP)=0.5*(U(IL,IP)+U(IL,IP-1))
0098      VM(IL,IP)=0.5*(V(IL,IP)+V(IL,IP-1))
0099      130  CONTINUE
      C
0100      CALL IRFLUX
      C
0101      RETURN
0102      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0094	LINE 0096 RHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES
LINE 0093	LINE 0094 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0078	LINE 0085 RHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES
LINE 0077	LINE 0078 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0061	LINE 0068 RHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES
LINE 0060	LINE 0061 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0048	LINE 0053 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0039	LINE 0045 LHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES
LINE 0022	LINE 0024 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0021	LINE 0022 NONVECTORIZABLE LOOP NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0020

NUMBER OF VECTORIZABLE LOOPS = 0010

NUMBER OF STACKLIBED LOOPS = 0000

```

0001      SUBROUTINE IRFLUX
      C
      C
0002      DIMENSION SV(72,20),SW(72,20),TUI1(72,20),TUI2(72,20)
0003      DIMENSION BAI(72,20),BWI(72,20)
0004      DIMENSION X1(72,20),X2(72,20),X3(72,20),X4(72,20),X5(72,20),
      1      X6(72,20),X7(72,20),X8(72,20)
0005      DIMENSION BH20V(25),BH20W(25),BLKC02(25),BLKWIN(25)
0006      DIMENSION FH(72,20),DH(72,20),F1(72,20),IT(72,20)
0007      DIMENSION SH(72,20),SG(72,20,20),SHT(72,20),SHU(72,20),SUM(72)
0008      DIMENSION A(72,20),B(72,20),C(72,20),WV(72,20),YV(72,20),

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1          ZV (72,20) ,WW (72,20) ,YW (72,20) ,ZW (72,20)
0009      DIMENSION D (72,20) ,E (72,20) ,F (72,20) ,TAUF (72,20) ,TXUF (72,20)
0010      COMMON/SH20/UBAR (72,20) ,VBAR (72,20) ,WBAR (72,20) ,UBARM (72,20) ,
1          VBARM (72,20) ,WBARM (72,20)
0011      COMMON/SC0203/PSCALV (72,20) ,PSCALW (72,20) ,U (72,20) ,V (72,20) ,
1          PSCAMV (72,20) ,PSCAMW (72,20) ,UM (72,20) ,VM (72,20)
0012      COMMON/INIT/NP,NPP1,NPM1
0013      COMMON/FLUX/FD (72,20) ,FU (72,20)
0014      COMMON/CSC/CSS (72,20) ,CCU (72,20) ,CH (72,20) ,CC (72,20)
1          ,          CS (72,20,20)
0015      COMMON/TEMP/TUI (72,20)
0016      DATA TEMP1/190./,DT/5./,NT/25/

C
C***** H2O PLANCK FUNCTION *****
C
0017      DATA BH20V/22661.,24086.,25575.,27135.,28775.,30506.,32339.,
*          34286.,36361.,38578.,40954.,43505.,46248.,49203.,52388.,
*          55824.,59532.,63533.,67849.,72502.,77516.,82913.,88717.,
*          94952.,101640./
0018      DATA BH20W/30708.,34405.,38417.,42763.,47461.,52529.,57985.,
*          63850.,70141.,76880.,84088.,91784.,99990.,108726.,118016.,
*          127881.,138344.,149429.,161160.,173561.,186659.,200478.,
*          215046.,230390.,246539./

C
C***** WINDOW PLANCK FUNCTION *****
C
0019      DATA BLKWIN/1944.,2377.,2877.,3450.,4102.,4838.,5664.,6585.,
*          7606.,8733.,9969.,11320.,13788.,14380.,16097.,
*          17944.,19923.,22038.,24292.,26685.,29221.,31902.,
*          34729.,37703.,40825./

C
C***** CO2 PLANCK FUNCTION *****
C
0020      DATA BLKCO2/18606.,21145.,23884.,26826.,29973.,33325.,36883.,
*          40647.,44617.,48792.,53170.,57750.,62530.,67509.,
*          72683.,78050.,83609.,89354.,95285.,101397.,107688.,
*          114155.,120794.,127601.,134574./
0021      DO 10 IP=1,NP
0022      DO 10 IL=1,72
0023      SHT (IL,IP)=0.
0024      SHU (IL,IP)=0.
0025      10 CONTINUE
0026      DO 15 IP=1,NP
0027      DO 15 IX=1,NP
0028      DO 15 IL=1,72
0029      SG (IL,IX,IP)=0.
0030      15 CONTINUE
0031      DO 20 IP=1,NPP1
0032      DO 20 IL=1,72
0033      FH (IL,IP)=(TUI (IL,IP)-TEMP1)/DT+1.5
0034      IT (IL,IP)=FH (IL,IP)
0035      IT (IL,IP)=MAXO (MINO (IT (IL,IP) ,NT-1) ,1)
0036      F1 (IL,IP)=FLOAT (IT (IL,IP)-1)
0037      DH (IL,IP)=TUI (IL,IP)-(TEMP1+F1 (IL,IP)*DT)
0038      SV (IL,IP)=BH20V (IT (IL,IP))+ (BH20V (IT (IL,IP)+1)-BH20V (IT (IL,IP)
1          ))*DH (IL,IP)/DT
0039      SW (IL,IP)=BH20W (IT (IL,IP))+ (BH20W (IT (IL,IP)+1)-BH20W (IT (IL,IP)
1          ))*DH (IL,IP)/DT
0040      BAI (IL,IP)=BLKCO2 (IT (IL,IP))+ (BLKCO2 (IT (IL,IP)+1)-BLKCO2 (IT
1          (IL,IP)))*DH (IL,IP)/DT

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0041      BWI (IL, IP) = BLKWIN (IT (IL, IP)) + (BLKWIN (IT (IL, IP) + 1) - BLKWIN (IT
1        (IL, IP))) * DH (IL, IP) / DT
0042      20 CONTINUE
0043      DO 30 IP=1, NPP1
0044      DO 30 IL=1, 72
0045      SH (IL, IP) = SV (IL, IP) + SW (IL, IP) + BAI (IL, IP) + BWI (IL, IP)
0046      TUI1 (IL, IP) = TUI (IL, IP) - 250.
0047      TUI2 (IL, IP) = TUI1 (IL, IP) * TUI1 (IL, IP)
0048      30 CONTINUE
C
C*****
C*****      H2O      *****
C*****
C
0049      DO 40 IP=2, NP
0050      DO 40 IL=1, 72
0051      A (IL, IP-1) = ABS (UBAR (IL, IP))
0052      B (IL, IP-1) = ABS (VBAR (IL, IP))
0053      C (IL, IP-1) = ABS (WBAR (IL, IP))
0054      40 CONTINUE
0055      JP = NPM1
C
C      CALL TABLE (JP, A, B, C, WV, YV, ZV, WW, YW, ZW)
0056      CALL GFUNC (JP, A, B, C, WV, YV, ZV, WW, YW, ZW)
C
0057      DO 45 IP=2, NP
0058      DO 45 IL=1, 72
0059      X1 (IL, IP) = WV (IL, IP-1) * SV (IL, 1)
0060      X2 (IL, IP) = 1. + YV (IL, IP-1) * TUI1 (IL, 1) + ZV (IL, IP-1) * TUI2 (IL, 1)
0061      X3 (IL, IP) = WW (IL, IP-1) * SW (IL, 1)
0062      X4 (IL, IP) = 1. + YW (IL, IP-1) * TUI1 (IL, 1) + ZW (IL, IP-1) * TUI2 (IL, 1)
0063      SHT (IL, IP) = X1 (IL, IP) * X2 (IL, IP) + X3 (IL, IP) * X4 (IL, IP)
0064      45 CONTINUE
0065      DO 50 IP=1, NPM1
0066      DO 50 IL=1, 72
0067      A (IL, IP) = ABS (UBAR (IL, NP) - UBAR (IL, IP))
0068      B (IL, IP) = ABS (VBAR (IL, NP) - VBAR (IL, IP))
0069      C (IL, IP) = ABS (WBAR (IL, NP) - WBAR (IL, IP))
0070      50 CONTINUE
0071      JP = NPM1
C
C      CALL TABLE (JP, A, B, C, WV, YV, ZV, WW, YW, ZW)
0072      CALL GFUNC (JP, A, B, C, WV, YV, ZV, WW, YW, ZW)
C
0073      DO 55 IP=1, NPM1
0074      DO 55 IL=1, 72
0075      X1 (IL, IP) = WV (IL, IP) * SV (IL, NPP1)
0076      X2 (IL, IP) = 1. + YV (IL, IP) * TUI1 (IL, NPP1) + ZV (IL, IP) * TUI2 (IL, NPP1)
0077      X3 (IL, IP) = WW (IL, IP) * SW (IL, NPP1)
0078      X4 (IL, IP) = 1. + YW (IL, IP) * TUI1 (IL, NPP1) + ZW (IL, IP) * TUI2 (IL, NPP1)
0079      X5 (IL, IP) = WV (IL, IP) * SV (IL, NP)
0080      X6 (IL, IP) = 1. + YV (IL, IP) * TUI1 (IL, NP) + ZV (IL, IP) * TUI2 (IL, NP)
0081      X7 (IL, IP) = WW (IL, IP) * SW (IL, NP)
0082      X8 (IL, IP) = 1. + YW (IL, IP) * TUI1 (IL, NP) + ZW (IL, IP) * TUI2 (IL, NP)
0083      SHU (IL, IP) = X1 (IL, IP) * X2 (IL, IP) + X3 (IL, IP) * X4 (IL, IP) -
1        X5 (IL, IP) * X6 (IL, IP) - X7 (IL, IP) * X8 (IL, IP)
0084      55 CONTINUE
C
C*****DOWNWARD FLUX SG (IX, IP) *****
C

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```

0085      DO 75 IP=2,NP
0086      DO 60 IX=2,IP
0087      DO 60 IL=1,72
0088      A(IL,IX-1)=ABS(UBAR(IL,IP)-UBARM(IL,IX))
0089      B(IL,IX-1)=ABS(VBAR(IL,IP)-VBARM(IL,IX))
0090      C(IL,IX-1)=ABS(WBAR(IL,IP)-WBARM(IL,IX))
0091      60 CONTINUE
0092      JP=IP-1

      C
      C
0093      CALL TABLE(JP,A,B,C,WV,YV,ZV,WW,YW,ZW)
      CALL GFUNC(JP,A,B,C,WV,YV,ZV,WW,YW,ZW)
      C

0094      DO 70 IX=2,IP
0095      DO 70 IL=1,72
0096      X1(IL,IX-1)=WV(IL,IX-1)*SV(IL,IX-1)
0097      X2(IL,IX-1)=1.+YV(IL,IX-1)*TUI1(IL,IX-1)+ZV(IL,IX-1)
      1      *TUI2(IL,IX-1)
0098      X3(IL,IX-1)=WW(IL,IX-1)*SW(IL,IX-1)
0099      X4(IL,IX-1)=1.+YW(IL,IX-1)*TUI1(IL,IX-1)+ZW(IL,IX-1)
      1      *TUI2(IL,IX-1)
0100      X5(IL,IX-1)=WV(IL,IX-1)*SV(IL,IX)
0101      X6(IL,IX-1)=1.+YV(IL,IX-1)*TUI1(IL,IX)+ZV(IL,IX-1)*TUI2(IL,IX)
0102      X7(IL,IX-1)=WW(IL,IX-1)*SW(IL,IX)
0103      X8(IL,IX-1)=1.+YW(IL,IX-1)*TUI1(IL,IX)+ZW(IL,IX-1)*TUI2(IL,IX)
0104      SG(IL,IX-1,IP)=X1(IL,IX-1)*X2(IL,IX-1)+X3(IL,IX-1)*X4(IL,IX-1)
      1      -X5(IL,IX-1)*X6(IL,IX-1)-X7(IL,IX-1)*X8(IL,IX-1)
0105      70 CONTINUE
0106      75 CONTINUE

      C
      C*****UPWARD FLUX SG(IX,IP)*****
      C

0107      DO 95 IP=1,NPM1
0108      IP1=NP-IP
0109      DO 80 IX=1,IP1
0110      DO 80 IL=1,72
0111      A(IL,IX)=ABS(UBAR(IL,IP)-UBARM(IL,IX+IP))
0112      B(IL,IX)=ABS(VBAR(IL,IP)-VBARM(IL,IX+IP))
0113      C(IL,IX)=ABS(WBAR(IL,IP)-WBARM(IL,IX+IP))
0114      80 CONTINUE
0115      JP=IP1

      C
      C
0116      CALL TABLE(JP,A,B,C,WV,YV,ZV,WW,YW,ZW)
      CALL GFUNC(JP,A,B,C,WV,YV,ZV,WW,YW,ZW)
      C

0117      DO 90 IX=1,IP1
0118      DO 90 IL=1,72
0119      X1(IL,IX)=WV(IL,IX)*SV(IL,IX+IP)
0120      X2(IL,IX)=1.+YV(IL,IX)*TUI1(IL,IX+IP)+ZV(IL,IX)*TUI2(IL,IX+IP)
0121      X3(IL,IX)=WW(IL,IX)*SW(IL,IX+IP)
0122      X4(IL,IX)=1.+YW(IL,IX)*TUI1(IL,IX+IP)+ZW(IL,IX)*TUI2(IL,IX+IP)
0123      X5(IL,IX)=WV(IL,IX)*SV(IL,IX+IP-1)
0124      X6(IL,IX)=1.+YV(IL,IX)*TUI1(IL,IX+IP-1)+ZV(IL,IX)
      1      *TUI2(IL,IX+IP-1)
0125      X7(IL,IX)=WW(IL,IX)*SW(IL,IX+IP-1)
0126      X8(IL,IX)=1.+YW(IL,IX)*TUI1(IL,IX+IP-1)+ZW(IL,IX)
      1      *TUI2(IL,IX+IP-1)
0127      SG(IL,IX+IP,IP)=X1(IL,IX)*X2(IL,IX)+X3(IL,IX)*X4(IL,IX)-
      1      X5(IL,IX)*X6(IL,IX)-X7(IL,IX)*X8(IL,IX)
0128      90 CONTINUE
0129      95 CONTINUE

```

```

C
C*****          *****
C*****          CO2 AND O3 *****
C*****          *****
C
0130      DO 140 IP=2,NP
0131      DO 140 IL=1,72
0132      A(IL,IP-1)=ABS(PSCALV(IL,IP))
0133      B(IL,IP-1)=ABS(PSCALW(IL,IP))
0134      C(IL,IP-1)=ABS(WBAR(IL,IP))
0135      D(IL,IP-1)=ABS(UBAR(IL,IP))
0136      E(IL,IP-1)=ABS(V(IL,IP))
0137      F(IL,IP-1)=ABS(U(IL,IP))
0138      140 CONTINUE
0139      JP=NPM1
C
0140      CALL TRC03(JP,A,B,C,D,E,F,TAUF,TXUF)
C
0141      DO 145 IP=2,NP
0142      DO 145 IL=1,72
0143      SHT(IL,IP)=SHT(IL,IP)+BAI(IL,1)*TAUF(IL,IP-1)
1          +BWI(IL,1)*TXUF(IL,IP-1)
0144      145 CONTINUE
0145      DO 150 IP=1,NPM1
0146      DO 150 IL=1,72
0147      A(IL,IP)=ABS(PSCALV(IL,NP)-PSCALV(IL,IP))
0148      B(IL,IP)=ABS(PSCALW(IL,NP)-PSCALW(IL,IP))
0149      C(IL,IP)=ABS(WBAR(IL,NP)-WBAR(IL,IP))
0150      D(IL,IP)=ABS(UBAR(IL,NP)-UBAR(IL,IP))
0151      E(IL,IP)=ABS(V(IL,NP)-V(IL,IP))
0152      F(IL,IP)=ABS(U(IL,NP)-U(IL,IP))
0153      150 CONTINUE
0154      JP=NPM1
C
0155      CALL TRC03(JP,A,B,C,D,E,F,TAUF,TXUF)
C
0156      DO 155 IP=1,NPM1
0157      DO 155 IL=1,72
0158      SHU(IL,IP)=SHU(IL,IP)+(BAI(IL,NPP1)-BAI(IL,NP))*TAUF(IL,IP)
1          +(BWI(IL,NPP1)-BWI(IL,NP))*TXUF(IL,IP)
0159      155 CONTINUE
C
C*****DOWNWARD FLUX SG(IX,IP)*****
C
0160      DO 175 IP=2,NP
0161      DO 160 IX=2,17
0162      DO 160 IL=1,72
0163      A(IL,IX-1)=ABS(PSCALV(IL,IP)-PSCAMV(IL,IX))
0164      B(IL,IX-1)=ABS(PSCALW(IL,IP)-PSCAMW(IL,IX))
0165      C(IL,IX-1)=ABS(WBAR(IL,IP)-WBARM(IL,IX))
0166      D(IL,IX-1)=ABS(UBAR(IL,IP)-UBARM(IL,IX))
0167      E(IL,IX-1)=ABS(V(IL,IP)-VM(IL,IX))
0168      F(IL,IX-1)=ABS(U(IL,IP)-UM(IL,IX))
0169      160 CONTINUE
0170      JP=IP-1
C
0171      CALL TRC03(JP,A,B,C,D,E,F,TAUF,TXUF)
C
0172      DO 170 IX=2,IP
0173      DO 170 IL=1,72

```

```

0174      SG(IL,IX-1,IP)=SG(IL,IX-1,IP)+(BAI(IL,IX-1)-BAI(IL,IX))
           1      *TAUF(IL,IX-1)+(BWI(IL,IX-1)-BWI(IL,IX))
           2      *TXUF(IL,IX-1)
0175      170 CONTINUE
0176      175 CONTINUE
C
C*****UPWARD FLUX SG(IX,IP)*****
C
0177      DO 195 IP=1,NPM1
0178      IP1=NP-IP
0179      DO 180 IX=1,IP1
0180      DO 180 IL=1,72
0181      A(IL,IX)=ABS(PSCALV(IL,IP)-PSCAMV(IL,IX+IP))
0182      B(IL,IX)=ABS(PSCALW(IL,IP)-PSCAMW(IL,IX+IP))
0183      C(IL,IX)=ABS(WBAR(IL,IP)-WBARM(IL,IX+IP))
0184      D(IL,IX)=ABS(UBAR(IL,IP)-UBARM(IL,IX+IP))
0185      E(IL,IX)=ABS(V(IL,IP)-VM(IL,IX+IP))
0186      F(IL,IX)=ABS(U(IL,IP)-UM(IL,IX+IP))
0187      180 CONTINUE
0188      JP=IP1
C
0189      CALL TRC03(JP,A,B,C,D,E,F,TAUF,TXUF)
C
0190      DO 190 IX=1,IP1
0191      DO 190 IL=1,72
0192      SG(IL,IX+IP,IP)=SG(IL,IX+IP,IP)+(BAI(IL,IX+IP)-BAI(IL,IX+IP-1))
           1      *TAUF(IL,IX)+(BWI(IL,IX+IP)-BWI(IL,IX+IP-1))
           2      *TXUF(IL,IX)
0193      190 CONTINUE
0194      195 CONTINUE
C
0195      CALL CLOUDS
C
0196      DO 210 IP=1,NP
0197      DO 210 IL=1,72
0198      FU(IL,IP)=0.
0199      FD(IL,IP)=0.
0200      210 CONTINUE
C
C***** COMPUTE DOWNWARD FLUXES *****
C
0201      DO 230 IP=2,NP
0202      DO 215 IL=1,72
0203      SUM(IL)=0.
0204      215 CONTINUE
0205      IPM1=IP-1
0206      DO 220 IX=1,IPM1
0207      DO 220 IL=1,72
0208      SUM(IL)=SUM(IL)+SG(IL,IX,IP)*CS(IL,IX,IP)
0209      220 CONTINUE
0210      DO 225 IL=1,72
0211      FD(IL,IP)=SUM(IL)-SHT(IL,IP)*CH(IL,IP)+SH(IL,IP)
0212      225 CONTINUE
0213      230 CONTINUE
C
C***** COMPUTE UPWARD FLUXES *****
C
0214      DO 250 IP=1,NPM1
0215      DO 235 IL=1,72
0216      SUM(IL)=0.

```

```

0217      235  CONTINUE
0218          IPP1=IP+1
0219          DO 240 IX=IPP1,NP
0220          DO 240 IL=1,72
0221              SUM(IL)=SUM(IL)+SG(IL,IX,IP)*CS(IL,IX,IP)
0222      240  CONTINUE
0223          DO 245 IL=1,72
0224              FU(IL,IP)=SUM(IL)+SHU(IL,IP)*CC(IL,IP)+SH(IL,IP)
0225      245  CONTINUE
0226      250  CONTINUE
0227          DO 260 IL=1,72
0228              FU(IL,NP)=SH(IL,NPP1)
0229      260  CONTINUE
0230          RETURN
0231          END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0214	LINE 0224 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0219	LINE 0221 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0201	LINE 0211 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0206	LINE 0208 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0177	LINE 0190 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0179	LINE 0186 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0160	LINE 0172 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0161	LINE 0168 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0156	LINE 0158 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0145	LINE 0152 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0141	LINE 0143 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0107	LINE 0117 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0109	LINE 0113 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0085	LINE 0094 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0086	LINE 0090 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0073	LINE 0082 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0065	LINE 0069 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0057	LINE 0062 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0031	LINE 0041 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0032	LINE 0035 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0026	LINE 0027 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0058

NUMBER OF VECTORIZABLE LOOPS = 0037

NUMBER OF STACKLIED LOOPS = 0000

```
0001      SUBROUTINE TABLE (N,A,B,C,WV,YV,ZV,WW,YW,ZW)
      C
      C
0002      DIMENSION KW(72,20),FW(72,20),KU(72,20),FU(72,20)
0003      DIMENSION ADEL(72,20),BDEL(72,20),WDEL(72,20)
0004      DIMENSION A(72,20),B(72,20),C(72,20),WV(72,20),YV(72,20),
      1      ZV(72,20),WW(72,20),YW(72,20),ZW(72,20)
0005      COMMON/INDAT/NUP1,NW
0006      COMMON/H2O/GL(30,20),COEFF(30,20,2)
0007      DATA SV/-6./,SW/-5.4/,DW/0.3/,DU/0.003/
0008      NU=NUP1-1
0009      DO 10 J=1,N
0010      DO 10 I=1,72
0011      B(I,J)=AMAX1(B(I,J),1.E-6)
0012      B(I,J)=ALOG10(B(I,J))
0013      KW(I,J)=(B(I,J)-SV)/DW+1.5001
0014      KW(I,J)=MINO(KW(I,J),NW-1)
0015      FW(I,J)=(B(I,J)-(SV+FLOAT(KW(I,J)-1)*DW))/DW
0016      ADEL(I,J)=(COEFF(KW(I,J)+1,NUP1,1)-COEFF(KW(I,J),NUP1,1))
      1      *FW(I,J)
0017      BDEL(I,J)=(COEFF(KW(I,J)+1,NUP1,2)-COEFF(KW(I,J),NUP1,2))
      1      *FW(I,J)
0018      WDEL(I,J)=(GL(KW(I,J)+1,NUP1)-GL(KW(I,J),NUP1))*FW(I,J)
0019      WV(I,J)=GL(KW(I,J),NUP1)+WDEL(I,J)
0020      WV(I,J)=AMAX1(WV(I,J),0.0)
0021      YV(I,J)=0.1*(COEFF(KW(I,J),NUP1,1)+ADEL(I,J))
0022      ZV(I,J)=0.001*(COEFF(KW(I,J),NUP1,2)+BDEL(I,J))
0023      KU(I,J)=A(I,J)/DU+1.5
0024      KU(I,J)=MINO(KU(I,J),NU-1)
0025      FU(I,J)=(A(I,J)-FLOAT(KU(I,J)-1)*DU)/DU
0026      C(I,J)=AMAX1(C(I,J),1.E-6)
0027      C(I,J)=ALOG10(C(I,J))
0028      C(I,J)=AMAX1(C(I,J),SW)
0029      KW(I,J)=(C(I,J)-SW)/DW+1.5001
0030      KW(I,J)=MINO(KW(I,J),NW-1)
0031      FW(I,J)=(C(I,J)-(SW+FLOAT(KW(I,J)-1)*DW))/DW
0032      ADEL(I,J)=(COEFF(KW(I,J)+1,KU(I,J),1)-COEFF(KW(I,J),KU(I,J),1))
      1      *FW(I,J)+(COEFF(KW(I,J),KU(I,J)+1,1)-COEFF(KW(I,J),KU(I,J),1))
      2      *FU(I,J)
0033      BDEL(I,J)=(COEFF(KW(I,J)+1,KU(I,J),2)-COEFF(KW(I,J),KU(I,J),2))
      1      *FW(I,J)+(COEFF(KW(I,J),KU(I,J)+1,2)-COEFF(KW(I,J),KU(I,J),2))
      2      *FU(I,J)
0034      WDEL(I,J)=(GL(KW(I,J)+1,KU(I,J))-GL(KW(I,J),KU(I,J)))*FW(I,J)+
      1      (GL(KW(I,J),KU(I,J)+1)-GL(KW(I,J),KU(I,J)))*FU(I,J)
0035      WW(I,J)=GL(KW(I,J),KU(I,J))+WDEL(I,J)
0036      WW(I,J)=AMAX1(WW(I,J),0.0)
0037      YW(I,J)=0.1*(COEFF(KW(I,J),KU(I,J),1)+ADEL(I,J))
0038      ZW(I,J)=0.001*(COEFF(KW(I,J),KU(I,J),2)+BDEL(I,J))
0039      10 CONTINUE
0040      RETURN
```

0041 END

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0010	LINE 0038 RHS ARRAY MUST BE REAL, INTEGER, LOGICAL, HALF PRECISION, OR COMPLEX
LINE 0009	LINE 0010 NONVECTORIZABLE LOOP NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0002

NUMBER OF VECTORIZABLE LOOPS = 0000

NUMBER OF STACKLIBED LOOPS = 0000

```

0001           SUBROUTINE GFUNC(N,A,B,C,WV,YV,ZV,WW,YW,ZW)
      C
      C
0002           DIMENSION A(72,20),B(72,20),C(72,20),WV(72,20),YV(72,20),
0003           1   ZV(72,20),WW(72,20),YW(72,20),ZW(72,20)
0003           DIMENSION A1(72,20),A2(72,20),A3(72,20),B1(72,20),B2(72,20),
0004           1   B3(72,20),B4(72,20),C1(72,20),C2(72,20),C3(72,20),C4(72,20)
0004           DO 20 J=1,N
0005           DO 20 I=1,72
0006           A1(I,J)=(1.0+32.2095*A(I,J))/(1.0+52.85*A(I,J))
0007           A2(I,J)=(0.534874+199.0*A(I,J)-1990.63*A(I,J)*A(I,J))/(1.0+
0008           1   333.244*A(I,J))
0008           A3(I,J)=(1.0+74.144*A(I,J))/(0.43368+24.7442*A(I,J))
0009           20 CONTINUE
0010           DO 30 J=1,N
0011           DO 30 I=1,72
0012           WW(I,J)=(A1(I,J)+A2(I,J)*SQRT(C(I,J)))/
0013           1   (1.0+A3(I,J)*SQRT(C(I,J)))
0013           WW(I,J)=AMAX1(WW(I,J),0.0)
0014           WV(I,J)=1.0/(1.0+9.22411*SQRT(B(I,J))+33.1236*B(I,J)+176.396
0015           1   *B(I,J)*B(I,J))
0015           WV(I,J)=AMAX1(WV(I,J),0.0)
0016           30 CONTINUE
0017           DO 40 J=1,N
0018           DO 40 I=1,72
0019           A(I,J)=AMIN1(A(I,J),0.06)
0020           B(I,J)=AMIN1(B(I,J),2.0)
0021           C(I,J)=AMIN1(C(I,J),8.0)
0022           40 CONTINUE
0023           DO 50 J=1,N
0024           DO 50 I=1,72
0025           YV(I,J)=0.1*(0.0851069*SQRT(B(I,J))+0.323105*B(I,J)-0.187096
0026           1   *B(I,J)*SQRT(B(I,J)))
0026           ZV(I,J)=0.001*(0.239186*B(I,J)-0.0922289*B(I,J)*SQRT(B(I,J))-
0027           1   0.0167413*B(I,J)*B(I,J))
0027           50 CONTINUE
0028           DO 60 J=1,N
0029           DO 60 I=1,72
0030           B1(I,J)=(5.6383E-4+1.05173*A(I,J)-39.0722*A(I,J)*A(I,J))
0031           1   /(1.0+202.357*A(I,J))
0031           B2(I,J)=(0.0779555+4.40720*A(I,J)+3.15851*A(I,J)*A(I,J))
0031           1   /(1.0+40.2298*A(I,J))

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0032      B3(I,J)=(-0.0381305-3.63684*A(I,J)+7.98951*A(I,J)*A(I,J))
1        / (1.0+62.5692*A(I,J))
0033      B4(I,J)=(0.00621039+0.710061*A(I,J)-2.85241*A(I,J)*A(I,J))
1        / (1.0+70.2912*A(I,J))
0034      YW(I,J)=0.1*(B1(I,J)+B2(I,J)*SQRT(C(I,J))+B3(I,J)*C(I,J)
1        +B4(I,J)*C(I,J)*SQRT(C(I,J)))
0035      60 CONTINUE
0036      DO 70 J=1,N
0037      DO 70 I=1,72
0038      C1(I,J)=(-2.99542E-4+0.238219*A(I,J)+0.519264*A(I,J)*A(I,J))
1        / (1.0+10.7775*A(I,J))
0039      C2(I,J)=(-0.0291325-2.30007*A(I,J)+10.9460*A(I,J)*A(I,J))
1        / (1.0+63.519*A(I,J))
0040      C3(I,J)=(0.0143812+1.80265*A(I,J)-10.1311*A(I,J)*A(I,J))
1        / (1.0+98.4758*A(I,J))
0041      C4(I,J)=(-0.00239016-0.371427*A(I,J)+2.35443*A(I,J)*A(I,J))
1        / (1.0+120.228*A(I,J))
0042      ZW(I,J)=0.001*(C1(I,J)+C2(I,J)*SQRT(C(I,J))+C3(I,J)*C(I,J)
1        +C4(I,J)*C(I,J)*SQRT(C(I,J)))
0043      70 CONTINUE
0044      RETURN
0045      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0018	LINE 0021 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0017	LINE 0018 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0011	LINE 0015 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0010	LINE 0011 NONVECTORIZABLE LOOP NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0012

NUMBER OF VECTORIZABLE LOOPS = 0008

NUMBER OF STACKLIBED LOOPS = 0000

```

0001      SUBROUTINE TRC03(N,A,B,C,D,E,F,TAUF,TXUF)
C
C
0002      DIMENSION A(72,20),B(72,20),C(72,20),D(72,20),E(72,20),F(72,20)
0003      DIMENSION TAUF(72,20),TXUF(72,20)
0004      DIMENSION XV(72,20),XW(72,20),XZ(72,20),DX(72,20),DY(72,20)
0005      DO 10 J=1,N
0006      DO 10 I=1,72
0007      XV(I,J)=3.1*A(I,J)/(1.+15.1*A(I,J)**0.56)
0008      XW(I,J)=0.04*B(I,J)/(1.+0.9*B(I,J)**0.57)
0009      DX(I,J)=6.7*C(I,J)/(1.+16.*C(I,J)**0.6)
0010      DY(I,J)=27.*D(I,J)**0.83
0011      XV(I,J)=XV(I,J)+DX(I,J)+DY(I,J)
0012      XW(I,J)=XW(I,J)+DX(I,J)+DY(I,J)
0013      XV(I,J)=AMIN1(XV(I,J),30.)
0014      XW(I,J)=AMIN1(XW(I,J),30.)
0015      TAUF(I,J)=0.384615384*EXP(-XV(I,J))+0.615384615*EXP(-XW(I,J))
0016      DY(I,J)=9.79*D(I,J)
0017      DY(I,J)=AMIN1(DY(I,J),30.)
0018      F(I,J)=F(I,J)/(E(I,J)*1013.25)

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0019      XZ(I,J)=4.*345.28*E(I,J)/(0.8796*F(I,J))
0020      XZ(I,J)=-4.398*F(I,J)*(SQRT(1.+XZ(I,J))-1.)
0021      XZ(I,J)=1.0-81.21/120.0*(1.0-EXP(XZ(I,J)))
0022      TXUF(I,J)=XZ(I,J)*EXP(-DY(I,J))
0023      10  CONTINUE
0024      RETURN
0025      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0006	LINE 0017 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0005	LINE 0006 NONVECTORIZABLE LOOP NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0002

NUMBER OF VECTORIZABLE LOOPS = 0000

NUMBER OF STACKLIED LOOPS = 0000

```

0001      SUBROUTINE CLOUDS
C
C
0002      COMMON/CSC/CSS(72,20),CCU(72,20),CH(72,20),CC(72,20)
0003      1,      CS(72,20,20)
0004      COMMON/INIT/NP,NPP1,NPM1
0005      DIMENSION CT(72,20),CU(72,20),CR(72,20,20)
0006      DO 10 IP=1,NP
0007      DO 10 IL=1,72
0008      CH(IL,IP)=1.0
0009      CC(IL,IP)=1.0
0010      CT(IL,IP)=1.0
0011      CU(IL,IP)=1.0
0012      10  CONTINUE
0013      DO 15 IP=1,NP
0014      DO 15 IX=1,NP
0015      DO 15 IL=1,72
0016      CS(IL,IX,IP)=1.0
0017      CR(IL,IX,IP)=1.0
0018      15  CONTINUE
0019      DO 20 IP=2,NP
0020      DO 20 IL=1,72
0021      CT(IL,IP)=1.-CCU(IL,IP-1)
0022      CT(IL,IP)=AMIN1(CT(IL,IP-1),CT(IL,IP))
0023      CH(IL,IP)=CH(IL,IP-1)*(1.-CSS(IL,IP-1))
0024      20  CONTINUE
0025      DO 30 IP=2,NP
0026      DO 30 IL=1,72
0027      CH(IL,IP)=CH(IL,IP)*CT(IL,IP)
0028      30  CONTINUE
0029      DO 40 I=1,NPM1
0030      IP=NP-I
0031      DO 40 IL=1,72
0032      CU(IL,IP)=1.-CCU(IL,IP)
0033      CU(IL,IP)=AMIN1(CU(IL,IP+1),CU(IL,IP))
0034      CC(IL,IP)=CC(JL,IP+1)*(1.-CSS(IL,IP))
0035      40  CONTINUE

```

```

0035      DO 50 I=1,NPM1
0036      IP=NP-1
0037      DO 50 IL=1,72
0038      CC(IL,IP)=CC(IL,IP)*CU(IL,IP)
0039  50    CONTINUE
0040      DO 60 IP=2,NP
0041      IPM1=IP-1
0042      DO 60 IX=1,IPM1
0043      DO 60 IL=1,72
0044      CR(IL,IX,IP)=1.-CCU(IL,IP-1)
0045      CR(IL,IX,IP)=AMIN1(CR(IL,IX,IP-1),CR(IL,IX,IP))
0046      CS(IL,IX,IP)=CS(IL,IX,IP-1)*(1.-CSS(IL,IP-1))
0047  60    CONTINUE
0048      DO 70 IP=2,NP
0049      IPM1=IP-1
0050      DO 70 IX=1,IPM1
0051      DO 70 IL=1,72
0052      CS(IL,IX,IP)=CS(IL,IX,IP)*CR(IL,IX,IP)
0053  70    CONTINUE
0054      DO 80 I=1,NPM1
0055      IP=NP-1
0056      IPP1=IP+1
0057      DO 80 IX=IPP1,NP
0058      DO 80 IL=1,72
0059      CR(IL,IX,IP)=1.-CCU(IL,IP)
0060      CR(IL,IX,IP)=AMIN1(CR(IL,IX,IP+1),CR(IL,IX,IP))
0061      CS(IL,IX,IP)=CS(IL,IX,IP+1)*(1.-CSS(IL,IP))
0062  80    CONTINUE
0063      DO 90 I=1,NPM1
0064      IP=NP-1
0065      IPP1=IP+1
0066      DO 90 IX=IPP1,NP
0067      DO 90 IL=1,72
0068      CS(IL,IX,IP)=CS(IL,IX,IP)*CR(IL,IX,IP)
0069  90    CONTINUE
0070      RETURN
0071      END

```

UNCOLLAPSIBLE LOOPS	REASON FOR NON-VECTORIZATION
LINE 0063	LINE 0066 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0054	LINE 0057 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0057	LINE 0061 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0058	LINE 0060 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0048	LINE 0050 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0040	LINE 0042 LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP
LINE 0043	LINE 0046 RHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES
LINE 0042	LINE 0043 NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0035	LINE 0038 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0028	LINE 0033 PROPERTY OF EMBEDDED LOOP PROHIBITS VECTORIZATION OF LOOP
LINE 0030	LINE 0032 STATEMENT CONTAINS NONVECTORIZABLE FUNCTION
LINE 0019	LINE 0022 RHS ARRAY HAS POSSIBLY RECURSIVE PROPERTIES

LINE 0018	LINE 0019	NONVECTORIZABLE LOOP NESTED WITHIN LOOP
LINE 0012	LINE 0013	LOOP WITH VARIABLE INITIAL/TERMINAL VALUE NESTED WITHIN LOOP

NUMBER OF LOOPS IN ROUTINE = 0025

NUMBER OF VECTORIZABLE LOOPS = 0011

NUMBER OF STACKLIBED LOOPS = 0000